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Report

New England
Marine Research Laboratory

FINAL REPORT

on

THE ACTIVITY OF *Limnoria tripunctata* IN PILING CUT-OFFS FROM NAPHTHALENE-ENRICHED CREOSOTED PILINGS

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by

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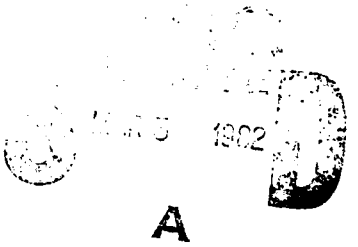

MANAGEMENT SUMMARY

Cut-offs from piling treated with creosote plus additional naphthalene at four levels were exposed to *Limnoria tripunctata* both in the laboratory and in the field.

After two years of exposure to active *Limnoria* attack in the laboratory and in the field, the 10 percent naphthalene additive samples showed the greatest resistance to attack by *Limnoria tripunctata*.

The treatment which showed the least resistance to *Limnoria tripunctata* under laboratory conditions was the 30 percent additive.

The treatment which showed the least resistance to *Limnoria tripunctata* in the field was the 20 percent additive.

Wedges coated with Bitumastic on the cut surface were not as heavily attacked by *Limnoria* as the wedges which were left uncoated.

A great deal of variation in the *Limnoria* attack among wedges of same treatments was observed, especially those cut from different discs.

Fouling organisms, especially barnacles were very heavy on discs during the first year of exposure at Daytona Beach, Florida. Molluscan borers, Pholadidae were found in small numbers in discs of all four percentages.

None of the samples put on exposure proved to be very effective against attack by *Limnoria tripunctata*.

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THE ACTIVITY OF *Limnoria tripunctata* IN PILING CUT-OFFS FROM NAPHTHALENE-ENRICHED CREOSOTED PILINGS

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INTRODUCTION

The need for an improved treatment for marine pilings has been recognized by both the United States Navy and industry. A satisfactory improved treatment must result in piling that will effectively prevent marine borer attack, resist breakage in handling and driving, and be economically feasible. Creosote-impregnated piling satisfies these needs except in areas where the wood-boring crustacean, *Limnoria tripunctata* exists, since *L. tripunctata* is relatively resistant to creosote.

Much has been accomplished in recent years towards improvement of treatments and development of new preservatives against borers and other destructive elements. Through cooperative efforts of industry and the Navy, a working-test exposure was installed in 1978 at Roosevelt Roads, Puerto Rico using piling treated with creosote containing the additive naphthalene in ranges of 10 to 40 percent. The piling cut-offs produced during this installation are being used for laboratory and field exposures to determine the preservative effectiveness of the added naphthalene.

OBJECTIVES

The objectives of this study are to determine the preservative effectiveness of various percentages of naphthalene-enriched creosote treatments exposed to *Limnoria tripunctata* attack in the laboratory and in a natural seawater environment; to determine if *Limnoria* attack is accelerated by exposure in the laboratory and to investigate if there are any seasonal differences in the rate of *Limnoria* attack in a natural environment where molluscan borers are also present.

MATERIALS AND METHODS

Three-inch discs from pile cut-offs were received at Battelle's New England Marine Facility - The William F. Clapp Laboratories in Duxbury, Massachusetts for laboratory exposure and Battelle's Florida Marine Research Facility in Daytona Beach, Florida for field exposure. A total of 38 discs, nine treated with 10 percent naphthalene creosote, 10 with 20 percent naphthalene creosote, 10 with 30 percent naphthalene creosote, and nine with 40 percent naphthalene creosote were to be used.

Laboratory Exposures

Three discs from each treatment were cut into eight pie-shaped segments, the heartwood removed, and the resulting wedge coated with Koppers Bitumastic 300 M on all surfaces except the outside circumferal surface. The uncoated surface of these wedges represents the area normally exposed to *Limnoria* attack on pilings. A fourth disc from each treatment was also cut into eight segments but was not coated. These wedges had the area normally inside a piling exposed to *Limnoria* attack also.

Twelve coated and four uncoated wedges per treatment were exposed to active *Limnoria tripunctata* attack in flowing seawater tables in the laboratory on October 31, 1979. An untreated soft pine coupon, measuring 73 mm x 103 mm x 18 mm, was added to each table to serve as a control. These samples comprised Series 1.

The second series of samples was placed in laboratory water tables on March 24, 1980, during a normally heavy *Limnoria* migrating season (March-April). During preparation of the discs on October 9, 1979, two of the discs were spoiled. Since replacements were not received, the second set of exposures was not a complete replicate of the first set. Only the 10 percent and 40 percent naphthalene creosote discs were available for the second series. Preparation and method of exposure were the same as used in Series 1.

Field Exposures

The cross-section surfaces of 16 discs (four per treatment) were drilled with a 5/8" (16 mm) center hole, coated with Koppers

Bitumastic 300 M on the sawn surfaces, mounted on four galvanized steel rods, and submerged vertically in the natural seawater environment at the Florida Marine Research Facility at Daytona Beach, Florida. Each rod held one disc from each treatment simulating an in-place piling. Four rods and discs for Series 1 were installed September 17, 1979; the remaining discs received were installed on two rods with three discs each for Series 2 on March 27, 1980. The order of arrangement of discs on the rods is shown in Table 1.

RESULTS AND DISCUSSION

Laboratory Exposures - Series 1

Inspections for *Limnoria* attack were performed monthly. The results of these inspections are shown in Table 2.

All treated wedges remained free of *Limnoria tripunctata* for over two months. By the end of the three-month exposure period, *Limnoria* had started tunneling into two of the coated 10 percent naphthalene creosote coated wedges which had one tunnel after three and four months exposure, and two tunnels at five months, none of the other wedges except the 10 percent coated wedges were attacked by *Limnoria* until after six months of exposure.

All of the treatments experienced the greatest percentage of increase in *Limnoria* tunnels in the period from 15 months to 18 months after initial exposure. This was during the quarter from February 1 to May 1, 1981 (Figure 1).

A great deal of variation in the *Limnoria* attack among wedges of same treatments was observed, especially in the 20% and 40% naphthalene additive samples (Table 3). Eight of the twelve wedges from each treatment were cut from one disc and the other four wedges were cut from another disc. In the 20% wedges, the mean of the eight wedges cut from one disc was 213 *Limnoria* tunnels after 24 months of exposure and the other four wedges showed a mean of 456 *Limnoria* tunnels. The 40% wedges showed this same type of variation with a mean of 189 *Limnoria* tunnels in the eight wedges cut from one disc and a mean of 530 *Limnoria* tunnels in the other four discs.

TABLE 1. ORDER OF DISC PLACEMENT ON ROD, FOR FIELD EXPOSURES OF DAYTONA BEACH, FLORIDA

Set					
1	2	3	4	5	6
10%	20%	30%	40%	30%	20%
20%	30%	40%	10%	20%	30%
30%	40%	10%	20%	20%	20%
40%	10%	20%	30%		

Sets 1-4 installed September, 1979.
Sets 5-6 installed March 27, 1980.

TABLE 2. NUMBER OF *Limnoria* TUNNELS IN WEDGES ON LABORATORY EXPOSURE - SERIES 1

Treatment	Sample Number	Months 3	6	9	12	15	18	21	24
10%	1	9	27	27	40	55	200	210	260
Naphthalene	2		1	1	2	32	80	165	170
Creosote	3					20	120	185	190
	4			19	31	105	270	325	370
(Coated)	5					21	90	125	190
	6					17	110	165	230
	7	67	70	70	73	110	250	310	350
	8		2	2	105	225	460	500	575
	9					24	105	170	240
	10		4	4	12	48	180	240	320
	11				42	85	190	235	250
	12				18	90	170	210	300
10%	1					26	140	210	500
	2	13	15	15	23	110	330	575	1000
(Uncoated)	3	15	15	15	48	130	280	400	950
	4	7	12	12	51	160	280	500	1100
20%	1				2	20	170	190	200
Naphthalene	2					6	58	120	220
Creosote	3						42	50	115
	4				1	6	14	30	95
(Coated)	5		1	1	44	85	210	220	230
	6				45	90	210	290	360
	7				7	24	90	155	185
	8				36	36	170	210	300
	9		3	7	90	235	380	420	450
	10	1	2	3	110	185	350	450	500
	11				71	160	270	340	375
	12				35	145	320	420	500
20%	1				67	260	350	600	900
	2		4	4	120	220	400	520	900
(Uncoated)	3				88	110	300	475	1000
	4				37	100	315	550	900
30%	1			4	200	310	360	430	460
Naphthalene	2				28	80	200	240	260
Creosote	3		5	5	47	110	225	250	290
	4			3	70	165	400	420	430
(Coated)	5		4	32	290	380	450	525	550
	6		19	86	185	380	440	475	510
	7		2	60	300	360	520	575	600
	8			31	140	260	350	375	420

TABLE 2. (continued)

Treatment	Sample Number	3	6	9	12	15	18	21	24
	9		1	1	35	135	270	280	290
	10		12	130	360	475	780	820	850
	11		8	92	275	300	370	410	430
	12			2	72	90	185	200	210
30%	1			65	250	380	610	675	950
	2		30	300	400	600	670	710	950
(Uncoated)	3		38	160	390	500	540	590	850
	4		8	65	190	340	450	500	800
40%	1				4	52	130	145	160
Naphthalene	2				26	130	280	290	300
Creosote	3				6	34	175	175	175
(Coated)	4				22	34	95	105	140
	5				14	20	100	120	145
	6				3	38	115	120	150
	7				32	140	210	220	230
	8				10	40	190	200	210
	9				140	250	335	380	450
	10				130	280	320	400	500
	11			7	300	420	500	530	600
	12		9	90	320	375	470	525	570
40%	1		40	300	450	525	630	690	900
	2		10	140	260	380	460	550	900
(Uncoated)	3		12	125	475	600	700	770	950
	4		19	280	380	460	590	620	850

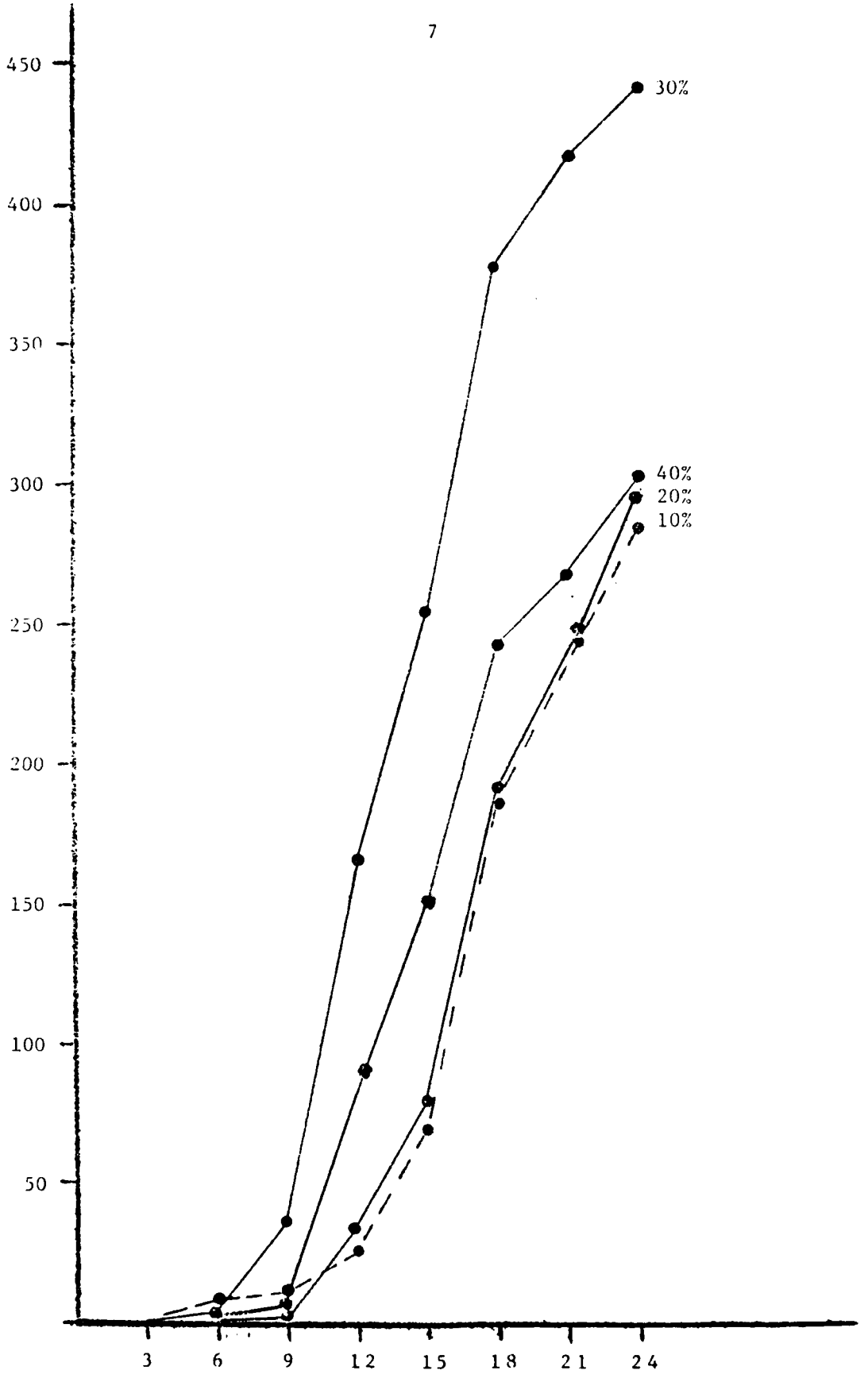

Figure 1. Rate of increase in *Limnoria* tunnels at 3-month intervals.

TABLE 3. MEAN NUMBER OF *Limnoria* TUNNELS IN LABORATORY WEDGES CUT FROM DIFFERENT DISCS

Series No. 1		
10% naphthalene	disc A	292
	disc B	278
	discs A & B	287
20% naphthalene	disc A	213
	disc B	456
	discs A & B	294
30% naphthalene	disc A	440
	disc B	445
	discs A & B	442
40% naphthalene	disc A	189
	disc B	530
	discs A & B	303

Wedges treated with the 10% naphthalene additive were the first to be attacked by *Limnoria*, but at the end of one year of exposure, these wedges appeared to be the most resistant to *Limnoria* attack. After two years exposure the mean number of tunnels in the 10% additive tests was numerically lower than any of the others (Table 4).

The mean number of *Limnoria* tunnels in the 20% and 40% naphthalene additive wedges at the end of two years of exposure was slightly higher than in the 10%. However, the difference among these three treatments was very slight and would be considered negligible. Wedges treated with a 30% naphthalene additive showed the heaviest attack in the laboratory exposures. These wedges had a mean of 442 tunnels per wedge as compared with a mean of 287 tunnels for the 10% treatments, which had the least attack.

There was some variation among the wedges in the area of wood exposed to *Limnoria* attack (Table 5). The exposed area of the wedges ranged from 63 to 132 square centimeters. The 40% naphthalene additive wedges averaged 25% smaller than the 10% wedges.

At the end of two years of exposure, the 10% wedges averaged 2.5 *Limnoria* tunnels per square centimeter, 20% wedges slightly higher with 2.7 tunnels per square centimeter, 40% wedges had 3.5 tunnels and the 30% wedges averaged 4.1 *Limnoria* tunnels per square centimeter.

Even though there was a variation in the size of the samples exposed, the overall ranking of naphthalene additive percentages remains in the same order.

Uncoated Wedges - Series 1

The wedges from each of the four treatments which were not coated on the inside surfaces were more heavily attacked than those wedges which were coated with Bitumastic on the cut edges. All of these wedges (four from each of four treatments) showed a similar attack after 24 months of exposure. The means ranged from 888 tunnels to 925 tunnels. This difference is not significant.

Wedges treated with 30% and 40% additive averaged three to five *Limnoria* tunnels per square centimeter as compared to .3 and .8

TABLE 4. MEAN NUMBER OF *Limnoria* TUNNELS IN LABORATORY WEDGES AT 3-MONTH INTERVALS

Series No.		Months 6	9	12	15	18	21	24
1	10% Coated	8.7	10.3	27	69.3	185.4	236.7	287.1
	10% Uncoated	9.3	9.3	30.5	106.5	257.5	421.3	887.5
	20% Coated	0.5	0.9	36.6	82.7	190.3	241.3	294.2
	20% Uncoated	1.0	1.0	78.0	172.5	341.3	536.3	925.0
	30% Coated	4.3	37.2	166.8	253.8	379.2	416.7	441.7
	30% Uncoated	19.0	147.5	307.5	455.0	567.5	618.8	887.5
	40% Coated	0.0	8.1	83.9	151.1	243.3	267.5	302.5
	40% Uncoated	20.3	211.3	391.3	491.3	595.0	657.5	900.0
2								
	10% Coated	5.5	11.0	17.3	76.7	206.8		
	10% Uncoated	0	3.5	5.3	49.0	128.3		
	40% Coated	0	6.3	10.1	16.0	58.3		
	40% Uncoated	52	155.0	183.8	251.3	310.0		

TABLE 5. AREA OF SURFACE EXPOSED TO *Limnoria tripunctata* OF SERIES 1 COATED WEDGES IN SQUARE CENTIMETERS

Wedges	10%	20%	30%	40%
1	105	115	114	74
2	119	125	112	82
3	121	104	118	88
4	130	67	108	65
5	113	117	102	63
6	106	122	104	103
7	114	105	117	86
8	124	132	108	72
9	80	99	104	103
10	125	122	128	106
11	96	113	100	79
12	135	102	106	111
Means	114	110	110	86

tunnels per square centimeter for 10% and 20% wedges at the one year interval of exposure. But, during the second year, all groups increased to 8 to 10 tunnels per square centimeter.

Laboratory Exposures - Series 2

In the second series of wedges exposed to *Limnoria* attack, the only instance of uncoated wedges with less attack than the coated wedges occurred with the 10% additive treated material (Table 6).

After 18 months of exposure, Series 2 uncoated wedges with 10% naphthalene only showed half as many *Limnoria* tunnels as the Series 1 10% naphthalene wedges.

The 40% coated wedges in Series 2 had the best performance of any of the treatments in both Series 1 and Series 2 after 18 months of exposure. The wedges had a mean of 58 tunnels.

Field Exposures - Series 1

There was a great deal of variation in the *Limnoria* attack among the discs of the various treatments on exposure at Daytona Beach, Florida (Table 7).

Some of this variation was due to the coverage of available surface by fouling, mainly barnacles. Very heavy fouling covered the discs at both of the March inspections, heavy fouling at the September, 1980 inspection and a light to moderate coverage at the September, 1981 inspection. The lighter fouling in September, 1981 was attributed to the erosion of the surface of the wood due to *Limnoria* attack. At each inspection period, all fouling was scraped off the discs, thus exposing more surface to *Limnoria* attack and settlement of fouling organisms every six months.

Field Exposure - Series 2

Four discs of the 20% naphthalene creosote and two discs of the 30% naphthalene creosote were put on exposure for Series 2. Two of the 20% additive discs were missing at the six-month inspection.

The remaining two discs of each treatment showed a mean *Limnoria* attack greater at 18 months than the mean of the four discs after 24 months of exposure in Series 1.

TABLE 6. NUMBER OF *Limnoria* TUNNELS IN WEDGES ON LABORATORY EXPOSURE - SERIES 2

Treatment	Sample Number	Months 3	6	9	12	15	18
10%	1		50	100	145	250	390
Naphthalene	2		11	11	19	140	300
Creosote	3			8	13	130	300
	4		3	4	7	80	200
(Coated)	5		2	8	13	95	280
	6				1	40	260
	7				2	18	170
	8				3	80	250
	9					13	90
	10					8	60
	11				4	60	150
	12					6	32
10%	1					4	33
	2			11	18	170	320
(Uncoated)	3					14	40
	4			3	3	8	120
40%	1				15	15	50
Naphthalene	2				3	3	22
Creosote	3			12	12	12	12
	4			6	14	28	150
(Coated)	5			7	7	12	44
	6			26	30	60	190
	7			14	15	15	16
	8			9	11	13	35
	9				3	9	40
	10				3	8	30
	11				8	11	70
	12					6	40
40%	1		18	125	145	260	290
	2		70	200	240	290	310
(Uncoated)	3		40	190	230	320	450
	4	2	80	105	120	135	190

TABLE 7. NUMBER OF *Limnoria* TUNNELS IN DISCS ON FIELD EXPOSURE

Set	Months Exposed	Treatment 10%	20%	30%	40%
1	6	0	0	0	0
	12	100	600	800	1300
	18	550	1700	900	1400
	24	700	7500	5560	9600
2	6	0	10	0	0
	12	1000	1300	400	1000
	18	1100	2000	1000	1700
	24	4160	9150	7200	8640
3	6	0	0	0	0
	12	4000	5500	200	1000
	18	4200	5600	800	3000
	24	8000	10560	8400	10300
4	6	0	0	0	0
	12	500	600	350	1300
	18	1200	1500	2000	1400
	24	5400	10100	10800	2000
5	6	-	1800 3000	2000	-
	12	-	1900 3100	2200	-
	18	-	9840 9600	10560	-
6	6	-	Lost	4000	-
	12	-	Lost	4500	-
	18	-	-	12150	-

Series 2 20% additive discs showed a mean of 9,720 tunnels at 18 months as compared with 9,328 tunnels at 24 months in Series 1. With the 30% additive, Series 2 had a mean of 11,355 *Limnoria* tunnels and 7,990 tunnels in Series 1.

Molluscan Borers in Florida Exposures

The molluscan borer, Pholadidae was present in the various piling cut-off discs on exposure in Florida (Table 8). Due to the heavy *Limnoria* attack in several of the discs, some of the Pholadidae which had bored into the wood during the first year of exposure were not found at the end of the second year. The wood was flaking off due to the *Limnoria* attack leaving the molluscs exposed where they were vulnerable to wave action. Small round depressions in the wood sometimes were the only evidence that this borer had been there the previous year. A total of 40 Pholadidae were present in the discs at the September, 1980 inspection and 36 Pholadidae were found at the September, 1981 inspection.

Comparison of Field and Laboratory Exposures

The piling cut-offs on exposure in Daytona Beach, Florida showed a heavier *Limnoria* attack than the coated laboratory exposure wedges (Table 9). With the exception of the 10% naphthalene uncoated wedges which had over two and one half times as many *Limnoria* tunnels as the 10% additive field exposure discs, the field exposures also were more severely attacked by *Limnoria* than the uncoated wedges exposed under laboratory conditions.

Field and laboratory exposures have indicated different results after two years of exposure. The 10% naphthalene discs were most successful in the field and the laboratory, but the 20% naphthalene showed the heaviest *Limnoria* attack in the field while the 30% naphthalene wedges showed the heaviest *Limnoria* attack in the laboratory.

In the field exposures, the order of best protection was 10%, 40%, 30%, and 20% respectively.

TABLE 8. NUMBER OF SPECIMENS OF PHOLADIDAE IN DISCS ON FIELD EXPOSURE

Inspections	9/80	9/81	9/80	9/81	9/80	9/81	9/80	9/81
				Treatments				
Set	10%		20%		30%		40%	
1	0	2	1	2	1	0	1	2
2	2	0	2	2	1	0	3	2
3	4	2	6	3	3	2	3	1
4	2	2	3	3	2	10	2	0
5	-	-	-	-	0	0	-	-
6	-	-	-	-	2	0	-	-

TABLE 9. MEAN NUMBER OF *Limnoria* IN DISCS AND RECONSTITUTED DISCS (exposed 24 months)

	10%	20%	30%	40%
Mean # of *Limnoria* Tunnels in discs	2585	9328	7990	7635
Mean # of *Limnoria* Tunnels in Reconstituted Disc (8 Wedges = 1 Disc) (Coated)	2296	2352	3536	2424
Mean # of *Limnoria* Tunnels in Reconstituted Disc (8 Wedges = 1 Disc) (Uncoated)	7104	7400	7104	7200

In the laboratory exposures, the order of best protection was 10%, 20%, 40% and 30%, respectively.

None of the treatments proved to be very effective against *Limnoria tripunctata* attack.

Water Temperatures

Water temperatures in the laboratory exposures ranged from a low of 1.5°C to a high of 32.5°C (Table 10). During the period from October to June, the sea water for laboratory exposures passes through a heat exchanger in order to maintain temperatures that will support the breeding and migration of *Limnoria* throughout the entire year. The extreme low of 1.5°C resulted from a temporary mechanical failure of the system.

The mean water temperature in the two years of laboratory exposure was 19.4°C.

The discs submerged at the Florida Marine Research Facility in Daytona Beach, Florida were subjected to a low of 7.0°C and a high of 28.5°C (Table 11). The average water temperature at the field site was 21.3°C during the period from September, 1979 through September, 1981.

TABLE 10. LABORATORY WATER TEMPERATURES °C FROM NOVEMBER, 1979 THROUGH OCTOBER, 1981

	High	Low	Average
1979			
November	22.5	15.5	19.9
December	32.5	10.0	18.4
1980			
January	22.5	16.5	19.1
February	22.5	14.0	18.6
March	27.0	15.5	19.3
April	21.5	18.5	19.9
May	22.5	18.0	20.9
June	20.0	18.0	19.3
July	21.0	17.5	18.9
August	22.5	18.5	20.1
September	21.5	14.0	18.0
October	20.5	15.5	18.8
November	25.5	15.5	18.8
December	25.0	17.0	19.5
1981			
January	22.5	1.5	18.6
February	24.5	20.0	22.6
March	24.5	19.5	21.5
April	24.5	15.5	21.3
May	25.0	20.5	22.8
June	19.0	14.5	17.4
July	22.5	16.5	18.5
August	20.5	16.0	19.3
September	20.5	13.5	18.5
October	21.5	10.0	16.6

Temperature readings based on daily 9:00 AM readings from Taylor Temperature Recorder.

TABLE 11. DAYTONA BEACH WATER TEMPERATURES °C FROM SEPTEMBER, 1979 THROUGH SEPTEMBER, 1981

	High	Low	Average
1979			
September	27.0	25.0	25.4
October	27.0	22.5	24.8
November	24.0	18.0	21.3
December	20.0	15.5	17.8
1980			
January	17.5	12.0	15.4
February	14.0	11.0	12.5
March	20.0	11.0	18.2
April	22.0	19.0	20.3
May	24.5	20.5	21.7
June	27.5	24.0	25.6
July	28.0	24.5	26.3
August	27.0	24.0	26.0
September	27.5	24.0	26.1
October	26.0	20.0	23.7
November	22.0	18.0	19.8
December	19.0	16.0	17.3
1981			
January	14.0	7.0	11.0
February	18.5	12.5	15.0
March	19.5	15.5	17.4
April	24.0	18.0	21.3
May	25.0	22.0	23.2
June	25.0	19.0	23.0
July	28.0	23.0	25.7
August	28.5	24.0	26.3
September	28.5	25.5	27.0